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Oberoi et al.

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(54) **SEALANT APPLICATION ASSEMBLY AND METHODS OF USE**

(71) Applicant: **The Boeing Company**, Arlington, VA (US)

(72) Inventors: **Harinder S. Oberoi**, Snohomish, WA (US); **Kevin Marion Barrick**, Kingston, WA (US); **Yuanxin Charles Hu**, Newcastle, WA (US); **Melissa Anne Johnson**, Puyallup, WA (US); **Laura Carolyn Foster**, Brier, WA (US)

(73) Assignee: **The Boeing Company**, Arlington, VA (US)

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B05C 1/06 (2006.01)

(52) **U.S. Cl.**
CPC ***A46B 11/063*** (2013.01); ***B05C 1/06*** (2013.01); *A46B 2200/20* (2013.01)

(58) **Field of Classification Search**
CPC A46B 11/063; A46B 2200/20; B05C 1/06; B05C 5/0216; B05C 17/00516
See application file for complete search history.

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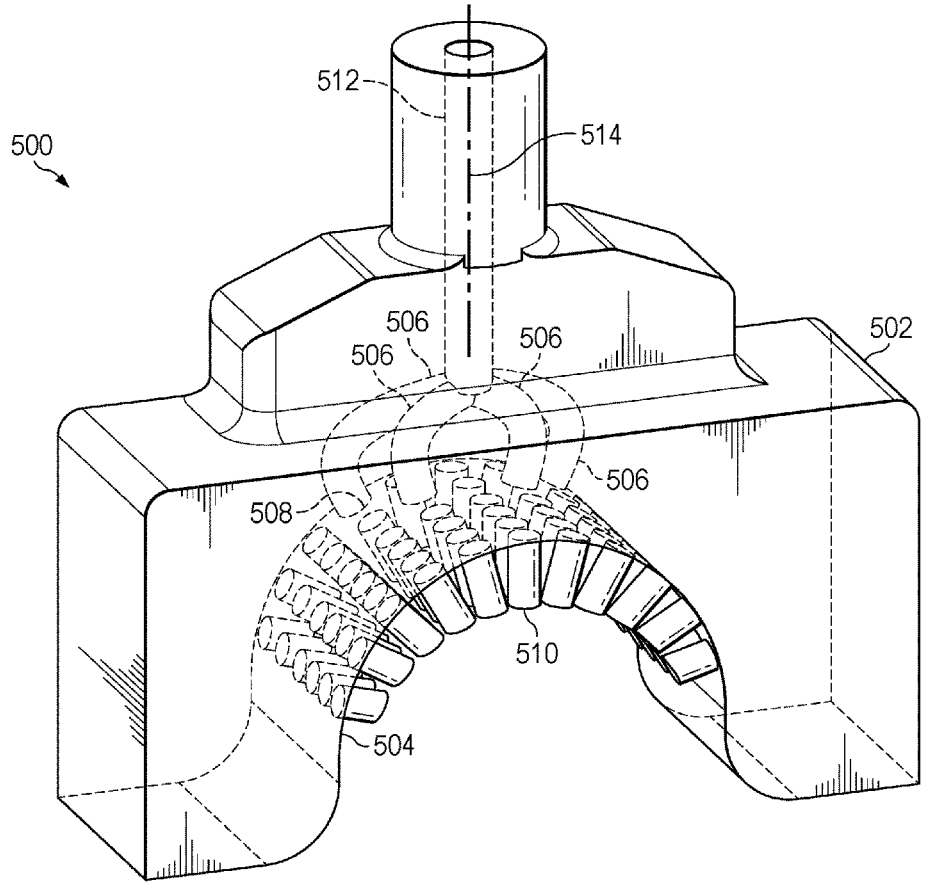
Primary Examiner — Alexander M Weddle
(74) *Attorney, Agent, or Firm* — Yee & Associates, P.C.

(57) **ABSTRACT**

A sealant application nozzle comprises a manifold with a incurvate face; bristles extending outward from the incurvate face; and channels within the manifold culminating in outlets exiting through the incurvate face to dispose sealant onto the incurvate face and base of the bristles.

28 Claims, 13 Drawing Sheets



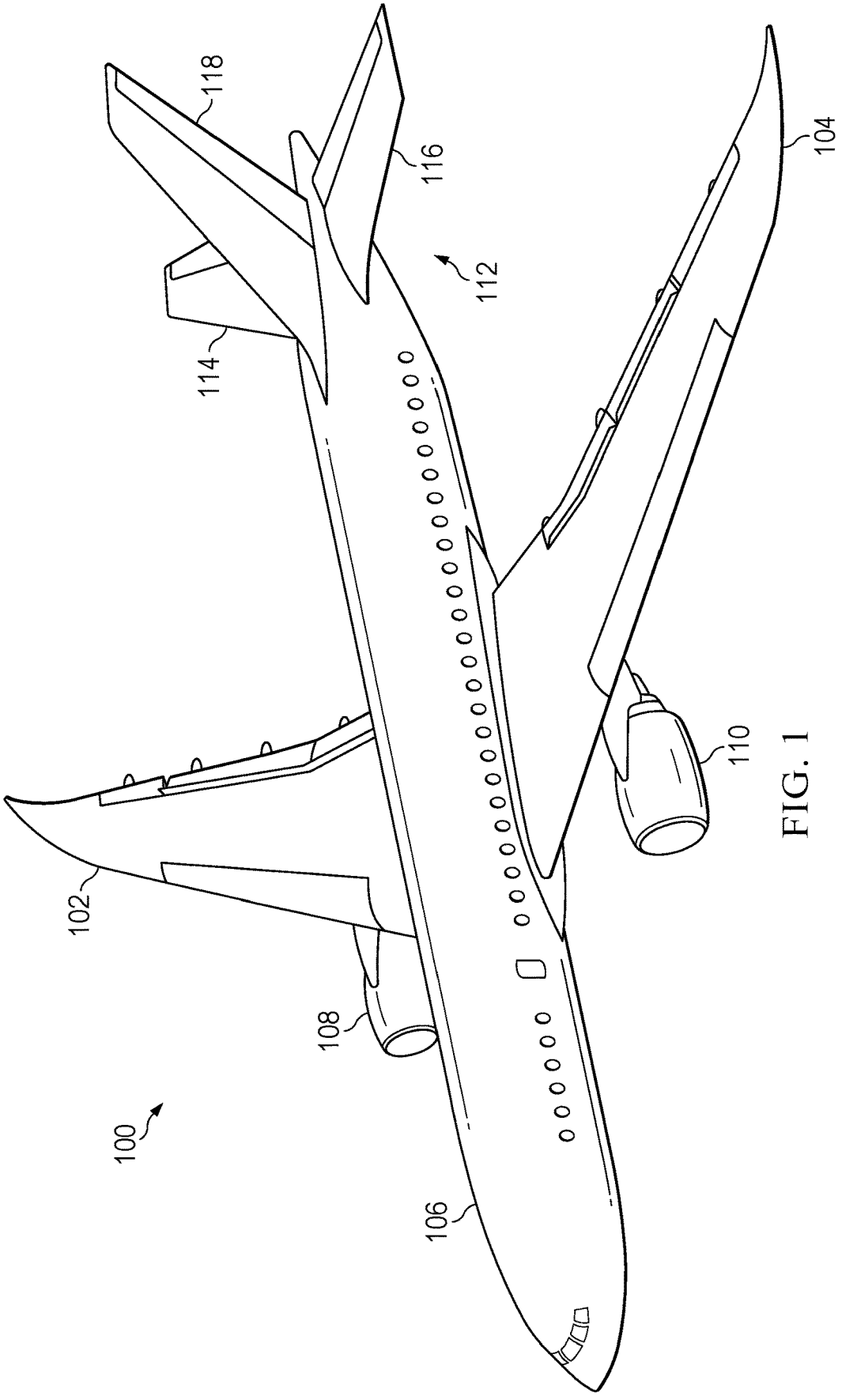


FIG. 1

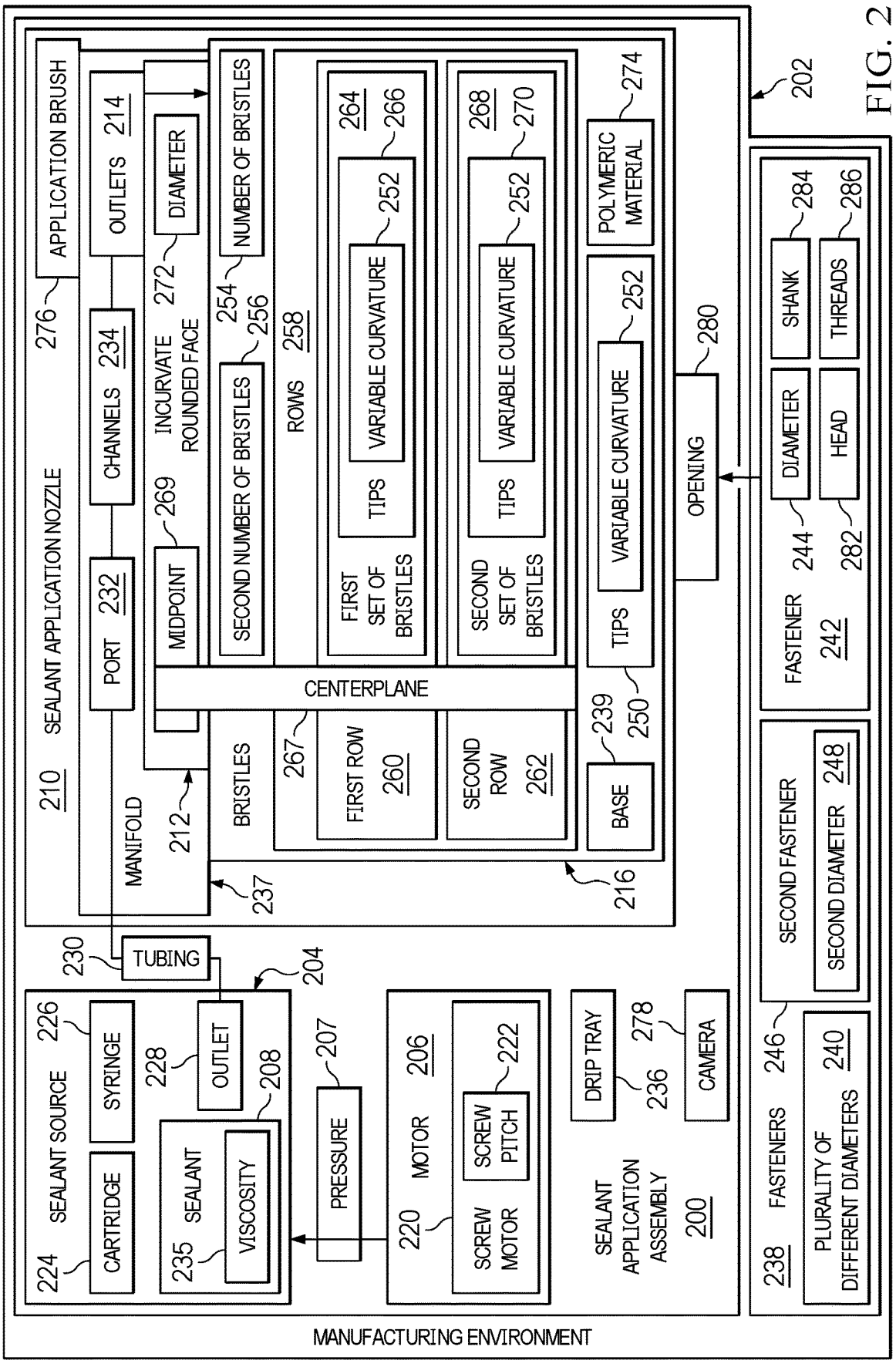

MANUFACTURING ENVIRONMENT
SEALANT APPLICATION ASSEMBLY 200
210 SEALANT APPLICATION NOZZLE
276 APPLICATION BRUSH
MANIFOLD 212
PORT 232
CHANNELS 234
OUTLETS 214
INCURVATE ROUNDED FACE 272
DIAMETER
MIDPOINT 269
NUMBER OF BRISTLES 254
SECOND NUMBER OF BRISTLES 256
ROWS 258
FIRST SET OF BRISTLES
SECOND SET OF BRISTLES
TIPS
VARIABLE CURVATURE 252
264
266
268
270
POLYMERIC MATERIAL 274
CENTERPLANE
BRISTLES 267
FIRST ROW 260
SECOND ROW 262
BASE 239
TIPS 250
VARIABLE CURVATURE 252
OPENING 280
237
216
202
FASTENER 242
DIAMETER 244
HEAD 282
SHANK 284
THREADS 286
SECOND FASTENER
SECOND DIAMETER 248
TUBING 230
204
SEALANT SOURCE 226
CARTRIDGE 224
SYRINGE
228
OUTLET 208
SEALANT 235
VISCOSITY
PRESSURE 207
MOTOR 206
SCREW MOTOR 220
SCREW PITCH 222
DRIP TRAY 236
278
CAMERA
FASTENERS 238
PLURALITY OF DIFFERENT DIAMETERS 240
246

FIG. 2

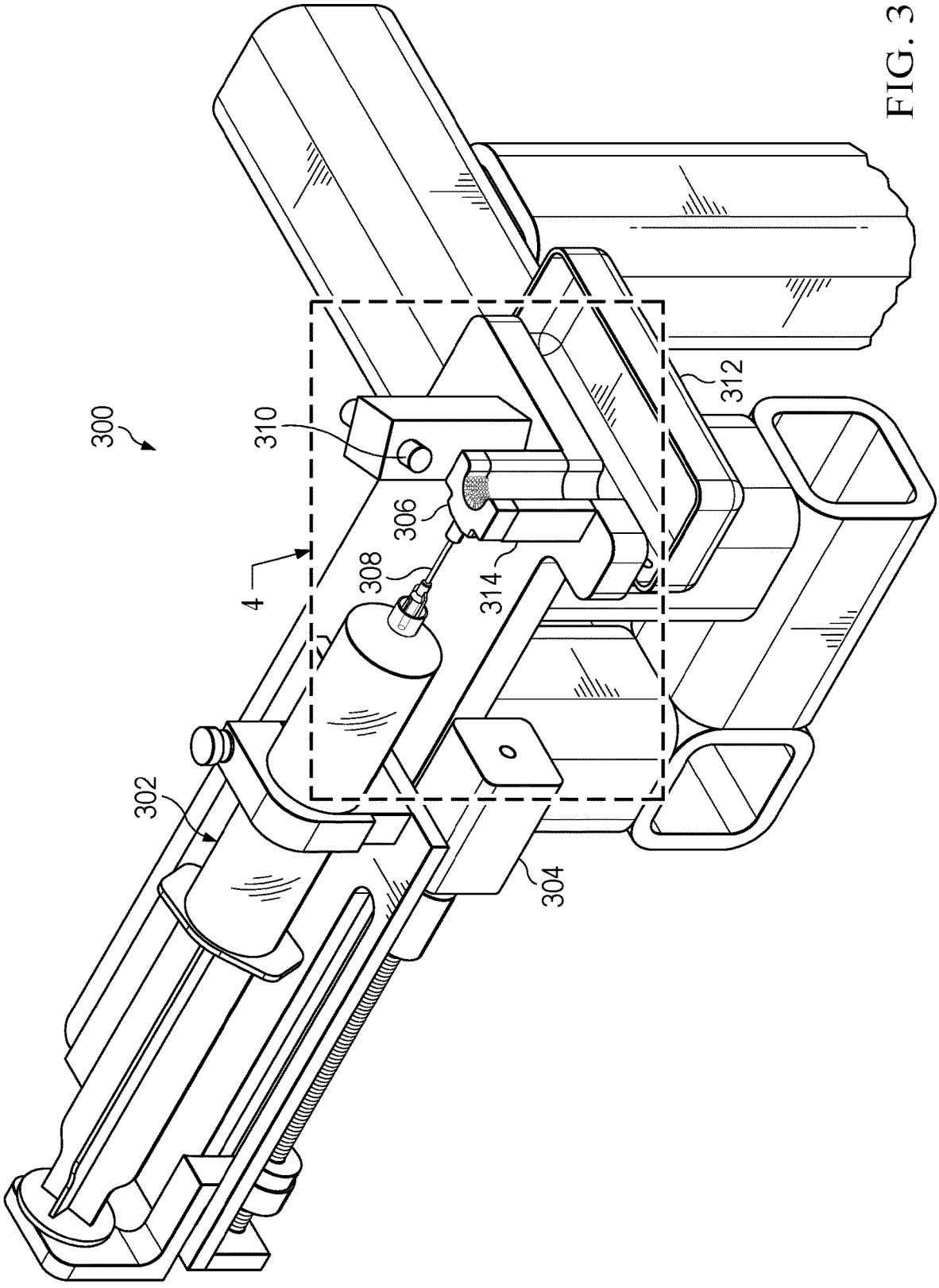


FIG. 3

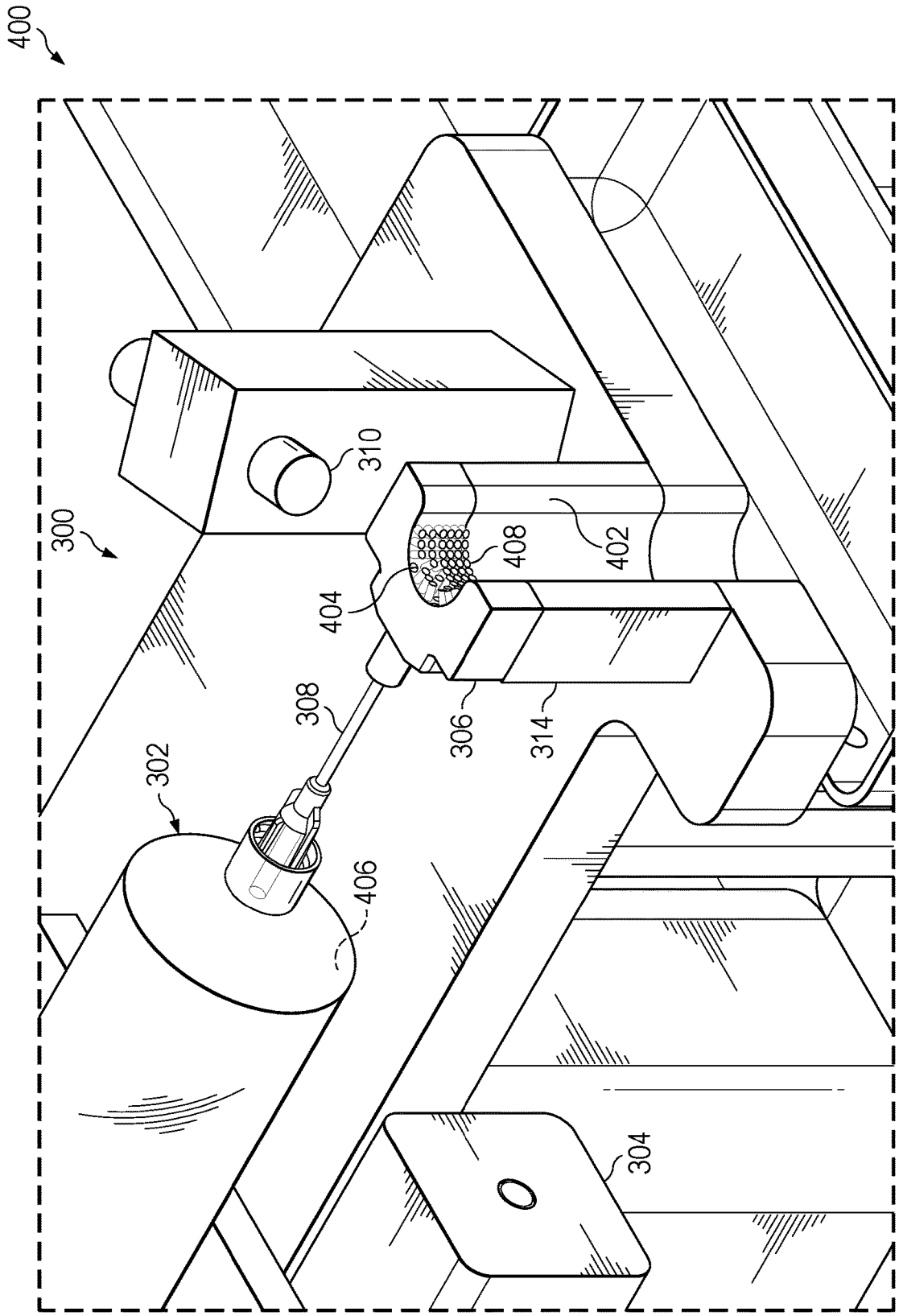


FIG. 4

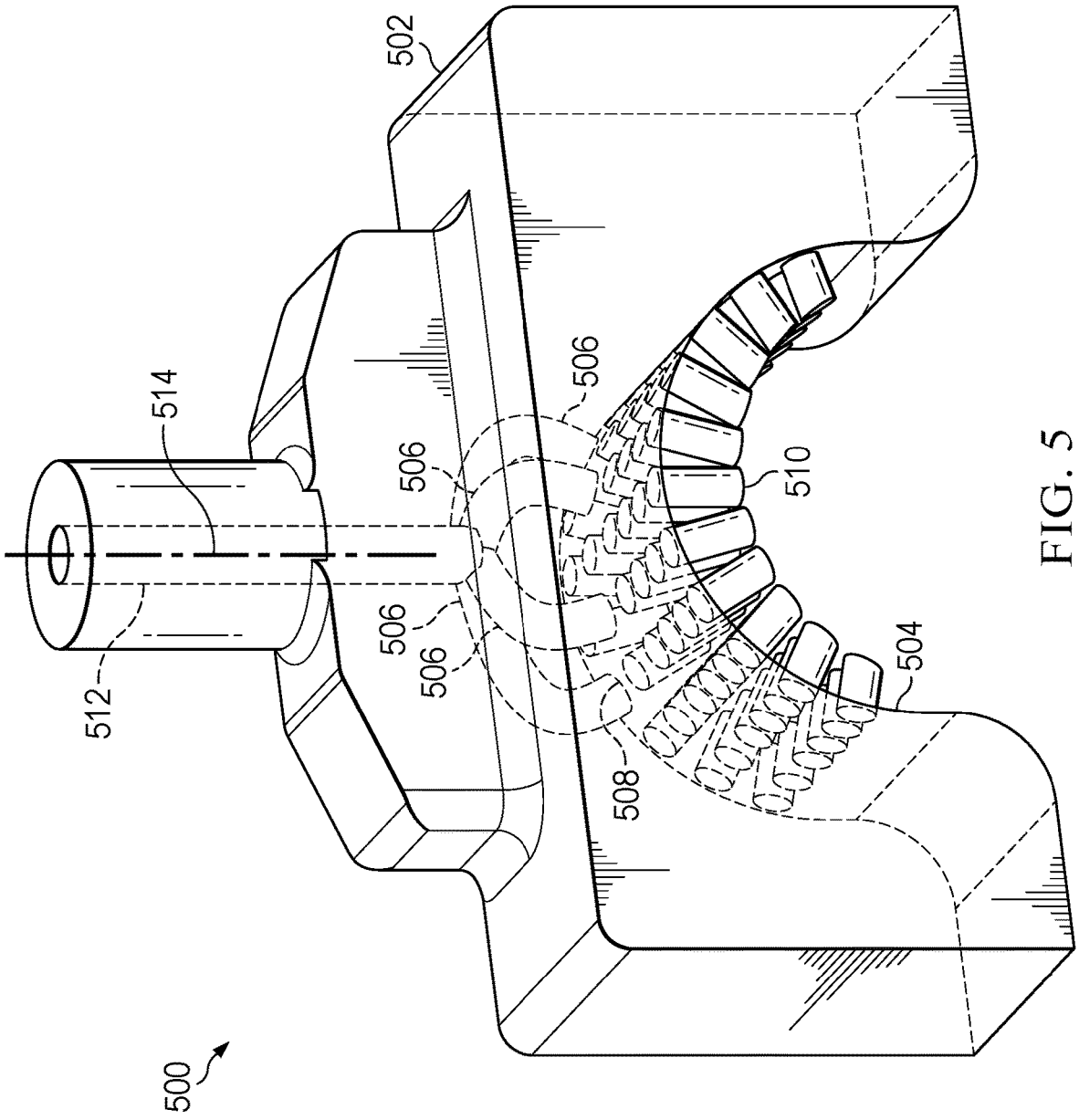


FIG. 5

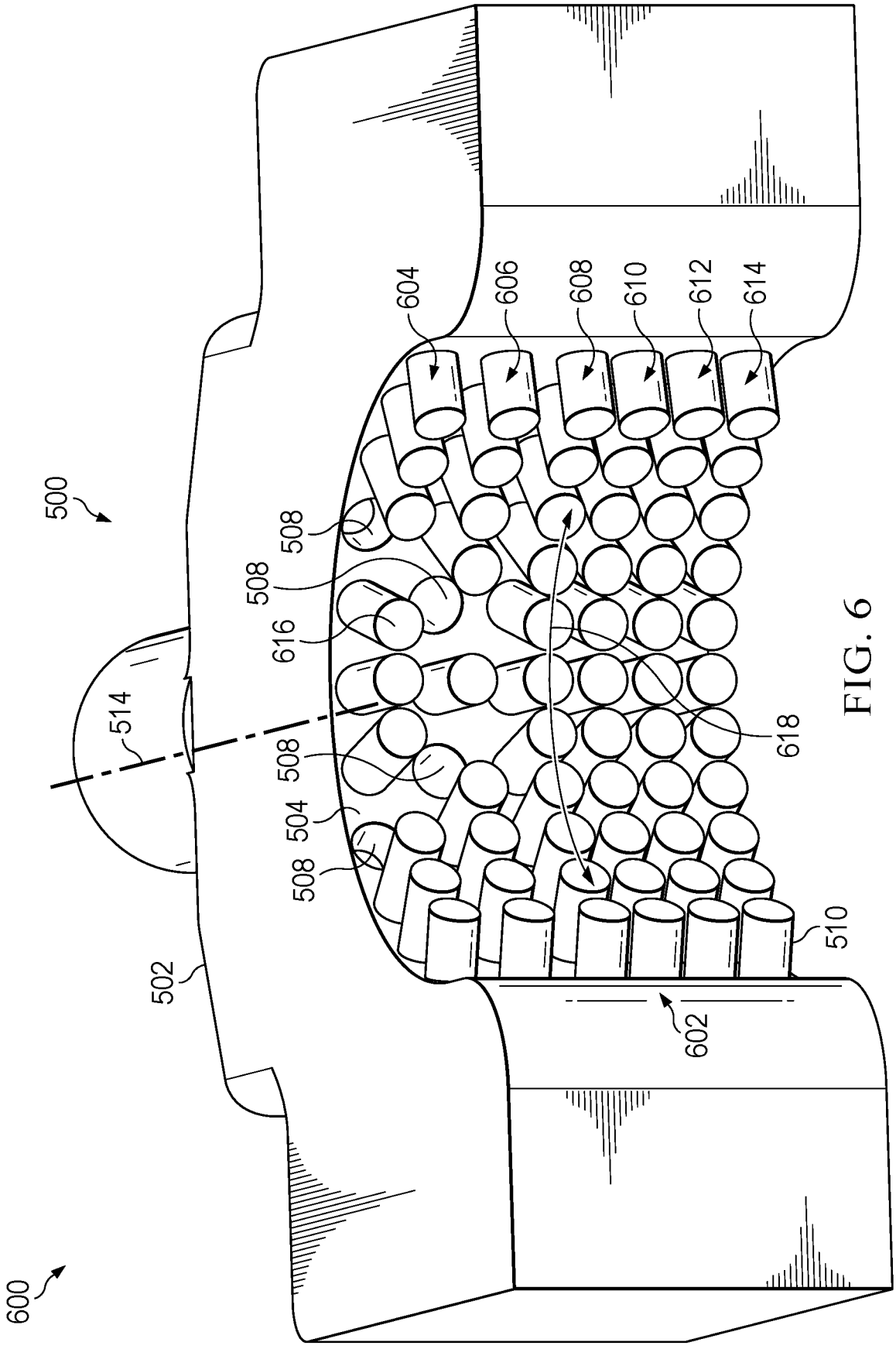

600
500
502
504
508
508
508
508
510
514
602
604
606
608
610
612
614
616
618

FIG. 6

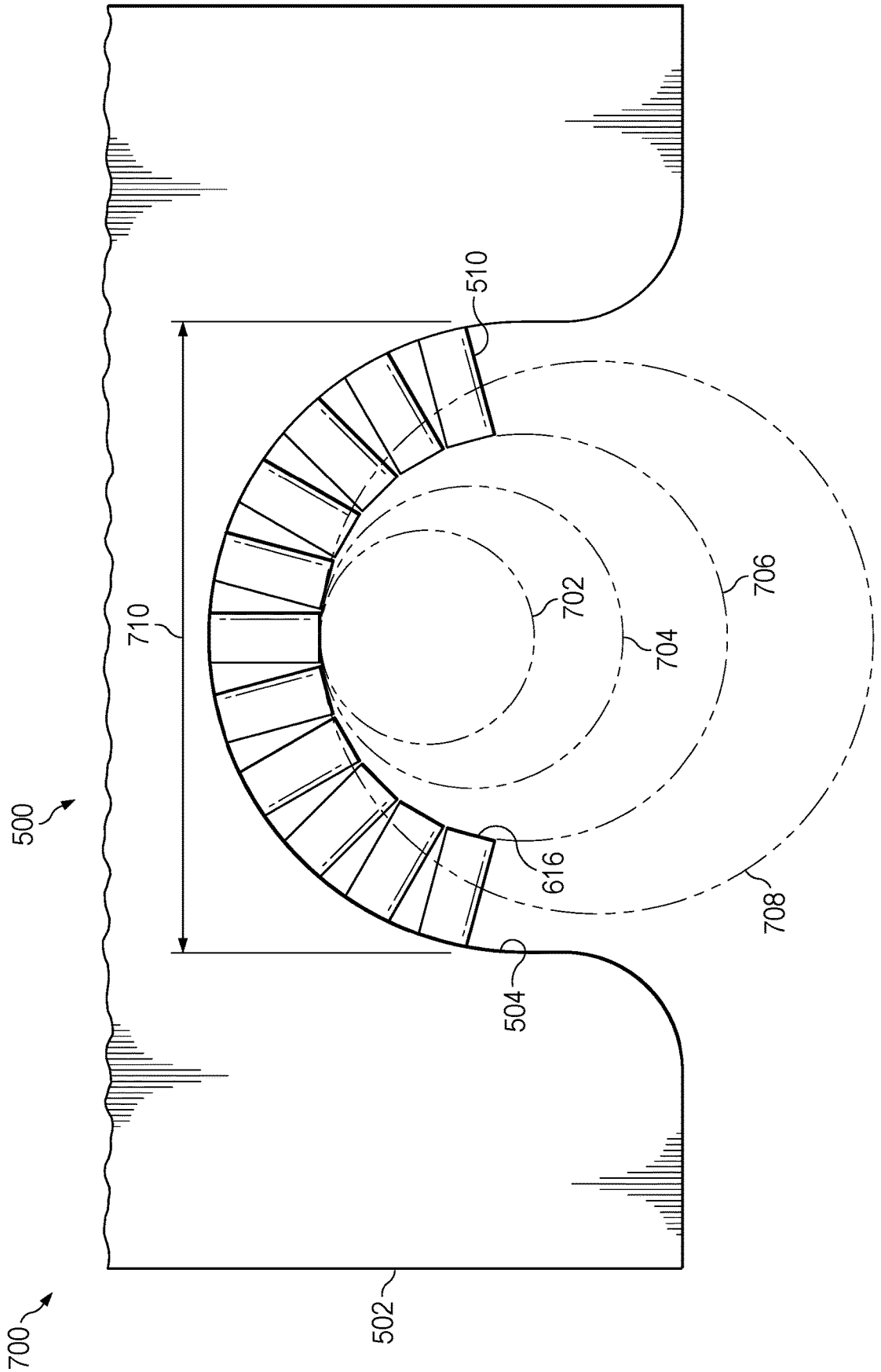


FIG. 7

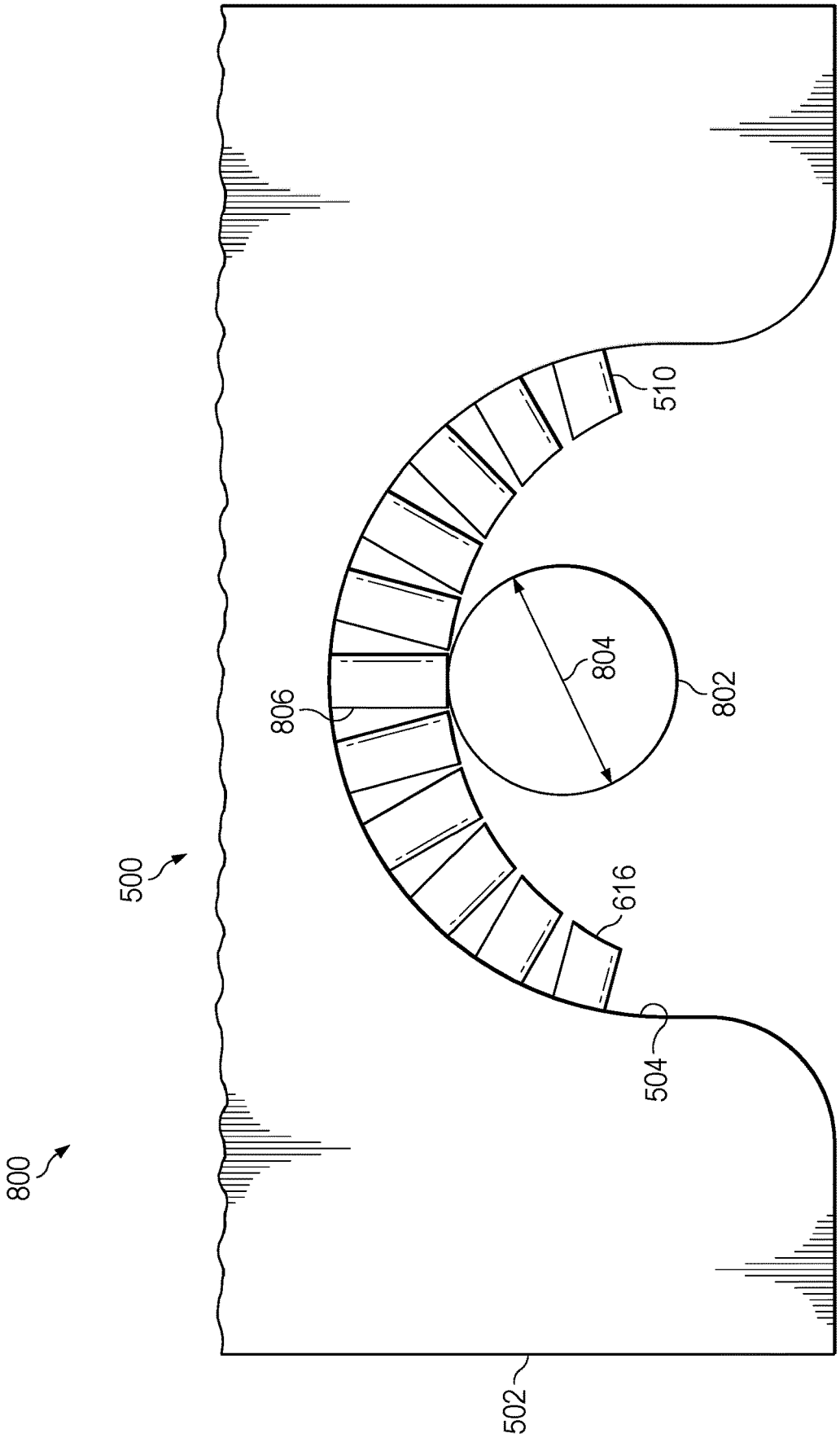


FIG. 8

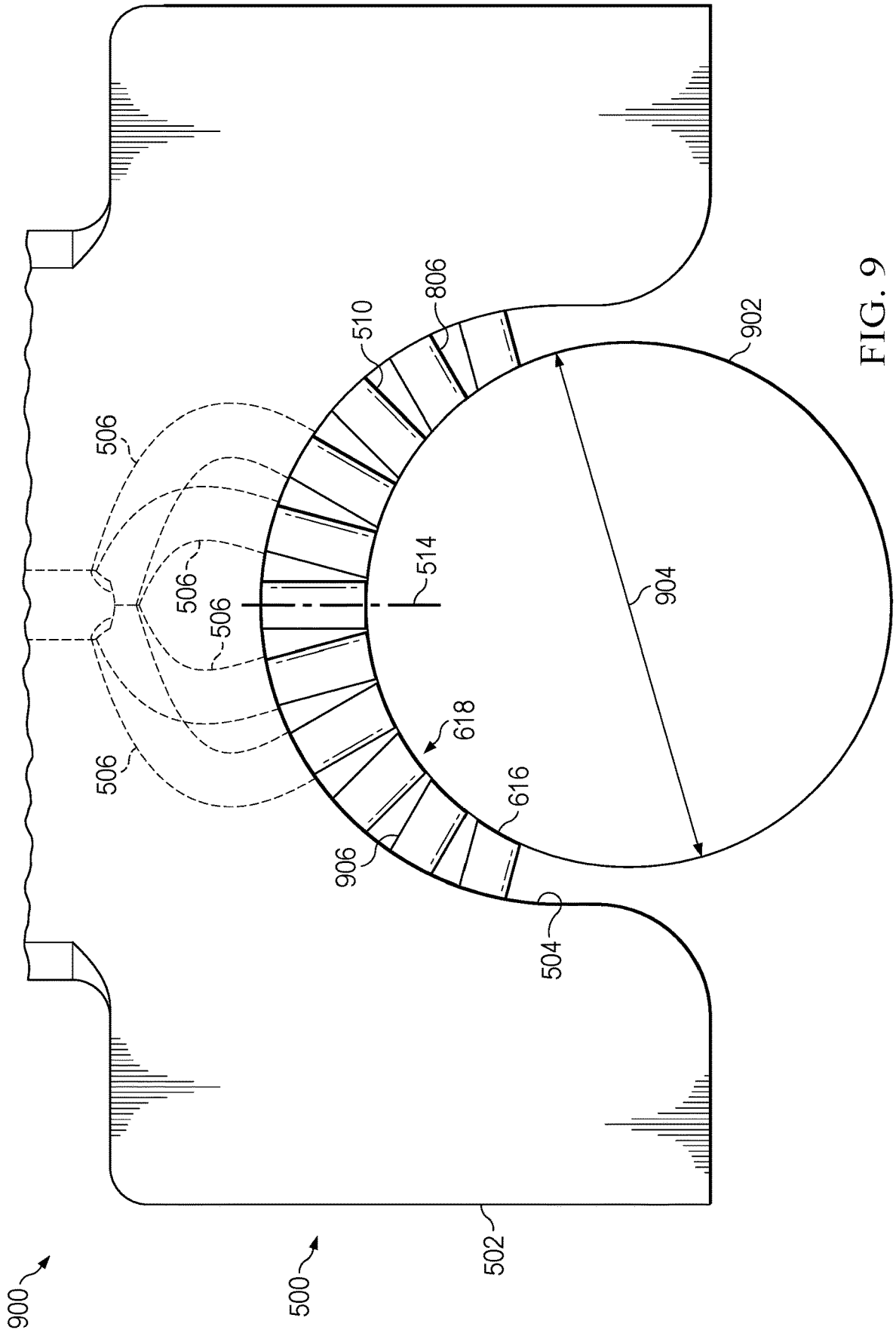


FIG. 9

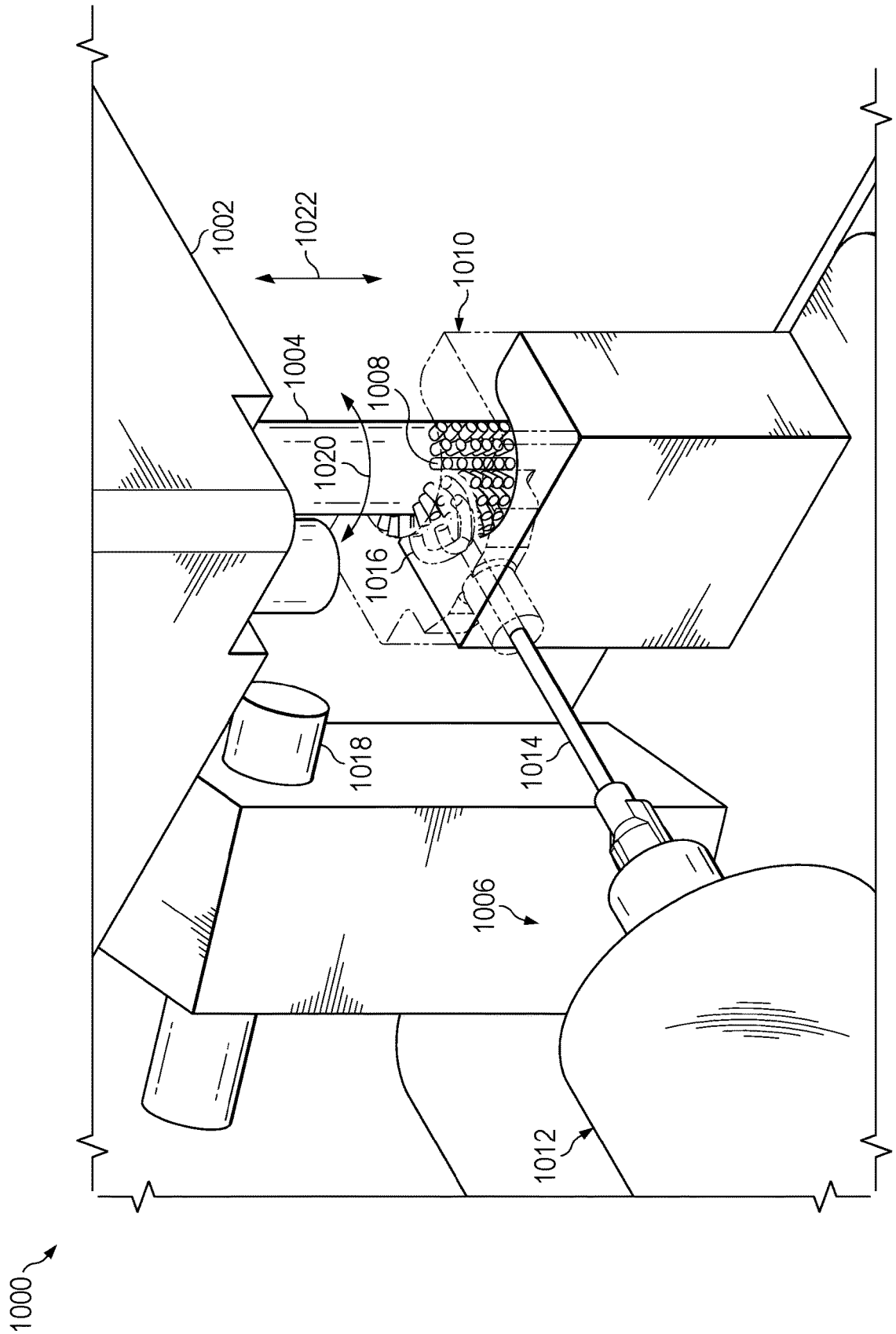


FIG. 10

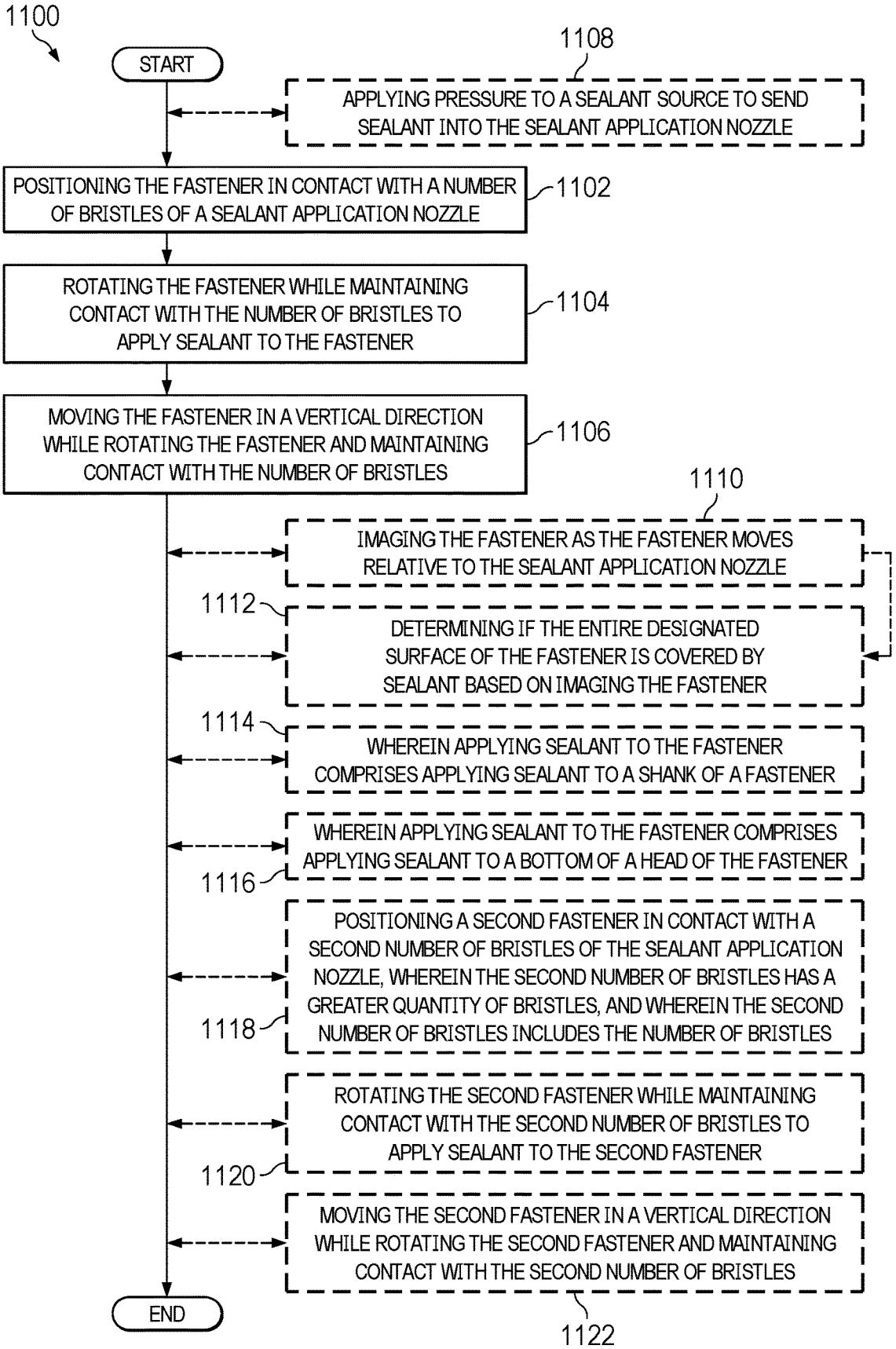

1100
START
1108
APPLYING PRESSURE TO A SEALANT SOURCE TO SEND SEALANT INTO THE SEALANT APPLICATION NOZZLE
POSITIONING THE FASTENER IN CONTACT WITH A NUMBER OF BRISTLES OF A SEALANT APPLICATION NOZZLE
1102
ROTATING THE FASTENER WHILE MAINTAINING CONTACT WITH THE NUMBER OF BRISTLES TO APPLY SEALANT TO THE FASTENER
1104
MOVING THE FASTENER IN A VERTICAL DIRECTION WHILE ROTATING THE FASTENER AND MAINTAINING CONTACT WITH THE NUMBER OF BRISTLES
1106
1110
IMAGING THE FASTENER AS THE FASTENER MOVES RELATIVE TO THE SEALANT APPLICATION NOZZLE
1112
DETERMINING IF THE ENTIRE DESIGNATED SURFACE OF THE FASTENER IS COVERED BY SEALANT BASED ON IMAGING THE FASTENER
1114
WHEREIN APPLYING SEALANT TO THE FASTENER COMPRISES APPLYING SEALANT TO A SHANK OF A FASTENER
WHEREIN APPLYING SEALANT TO THE FASTENER COMPRISES APPLYING SEALANT TO A BOTTOM OF A HEAD OF THE FASTENER
1116
POSITIONING A SECOND FASTENER IN CONTACT WITH A SECOND NUMBER OF BRISTLES OF THE SEALANT APPLICATION NOZZLE, WHEREIN THE SECOND NUMBER OF BRISTLES HAS A GREATER QUANTITY OF BRISTLES, AND WHEREIN THE SECOND NUMBER OF BRISTLES INCLUDES THE NUMBER OF BRISTLES
1118
ROTATING THE SECOND FASTENER WHILE MAINTAINING CONTACT WITH THE SECOND NUMBER OF BRISTLES TO APPLY SEALANT TO THE SECOND FASTENER
1120
MOVING THE SECOND FASTENER IN A VERTICAL DIRECTION WHILE ROTATING THE SECOND FASTENER AND MAINTAINING CONTACT WITH THE SECOND NUMBER OF BRISTLES
END
1122

FIG. 11

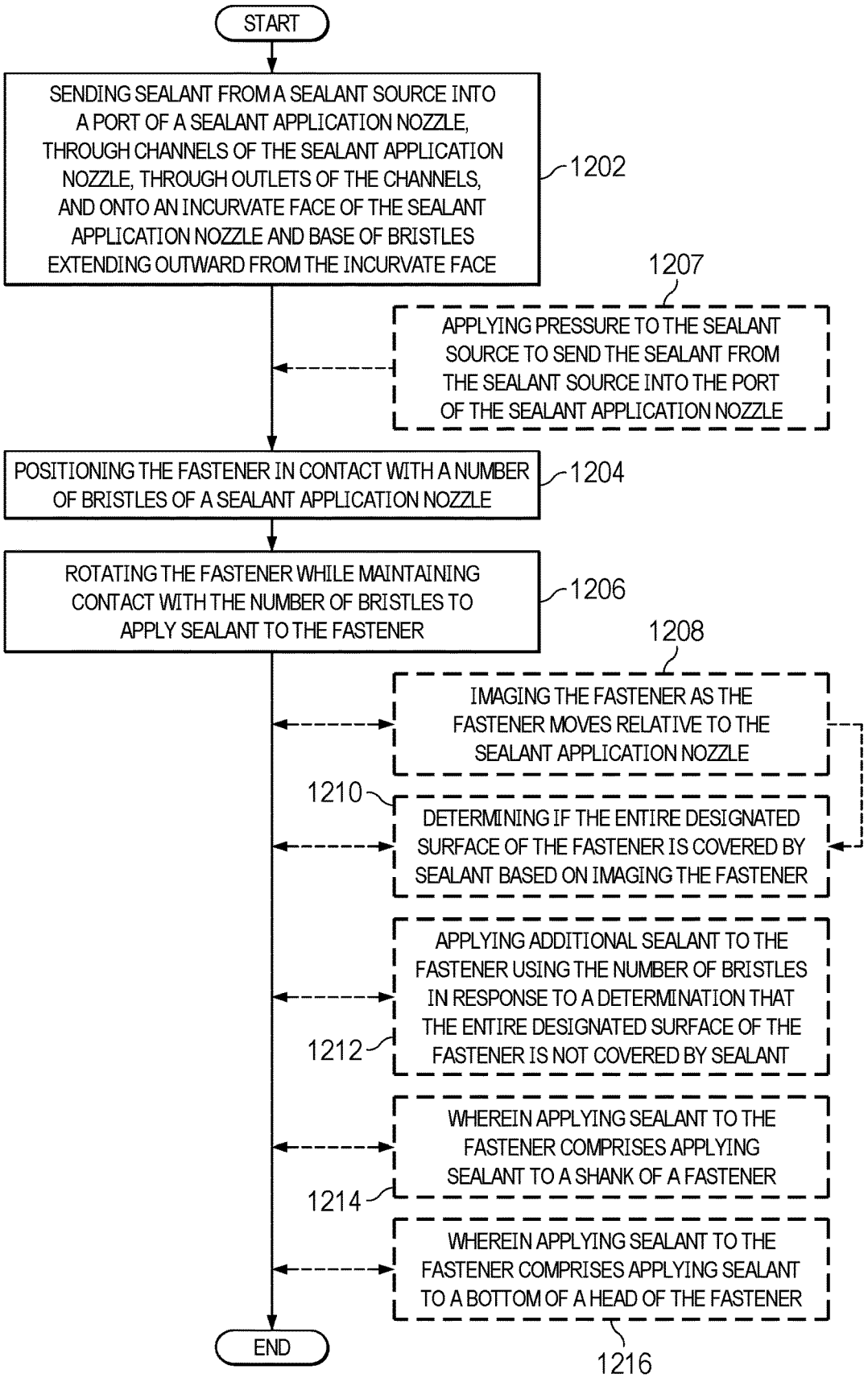

START
SENDING SEALANT FROM A SEALANT SOURCE INTO A PORT OF A SEALANT APPLICATION NOZZLE, THROUGH CHANNELS OF THE SEALANT APPLICATION NOZZLE, THROUGH OUTLETS OF THE CHANNELS, AND ONTO AN INCURVATE FACE OF THE SEALANT APPLICATION NOZZLE AND BASE OF BRISTLES EXTENDING OUTWARD FROM THE INCURVATE FACE
1202
1207
APPLYING PRESSURE TO THE SEALANT SOURCE TO SEND THE SEALANT FROM THE SEALANT SOURCE INTO THE PORT OF THE SEALANT APPLICATION NOZZLE
POSITIONING THE FASTENER IN CONTACT WITH A NUMBER OF BRISTLES OF A SEALANT APPLICATION NOZZLE
1204
ROTATING THE FASTENER WHILE MAINTAINING CONTACT WITH THE NUMBER OF BRISTLES TO APPLY SEALANT TO THE FASTENER
1206
1208
IMAGING THE FASTENER AS THE FASTENER MOVES RELATIVE TO THE SEALANT APPLICATION NOZZLE
1210
DETERMINING IF THE ENTIRE DESIGNATED SURFACE OF THE FASTENER IS COVERED BY SEALANT BASED ON IMAGING THE FASTENER
APPLYING ADDITIONAL SEALANT TO THE FASTENER USING THE NUMBER OF BRISTLES IN RESPONSE TO A DETERMINATION THAT THE ENTIRE DESIGNATED SURFACE OF THE FASTENER IS NOT COVERED BY SEALANT
1212
WHEREIN APPLYING SEALANT TO THE FASTENER COMPRISES APPLYING SEALANT TO A SHANK OF A FASTENER
1214
WHEREIN APPLYING SEALANT TO THE FASTENER COMPRISES APPLYING SEALANT TO A BOTTOM OF A HEAD OF THE FASTENER
1216
END

FIG. 12

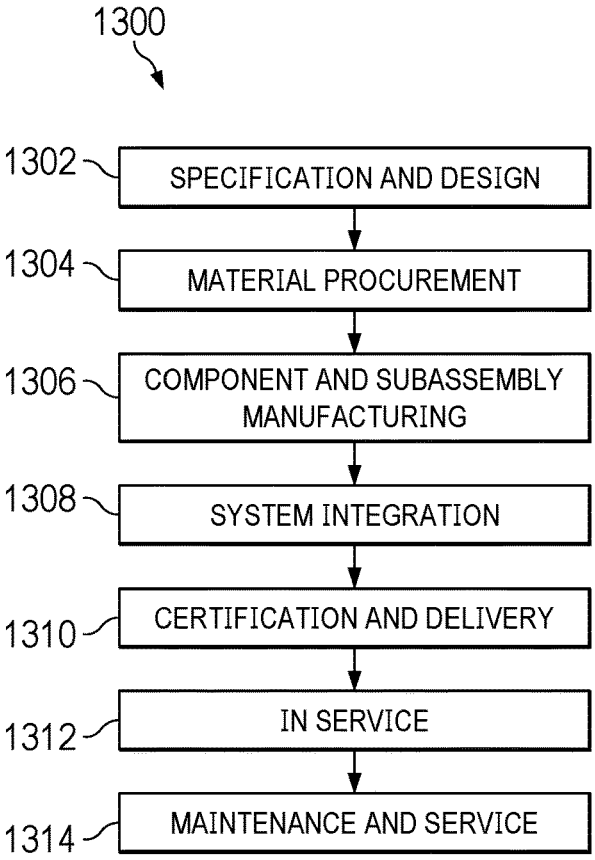

1300
1302
SPECIFICATION AND DESIGN
1304
MATERIAL PROCUREMENT
1306
COMPONENT AND SUBASSEMBLY MANUFACTURING
1308
SYSTEM INTEGRATION
1310
CERTIFICATION AND DELIVERY
1312
IN SERVICE
1314
MAINTENANCE AND SERVICE

FIG. 13

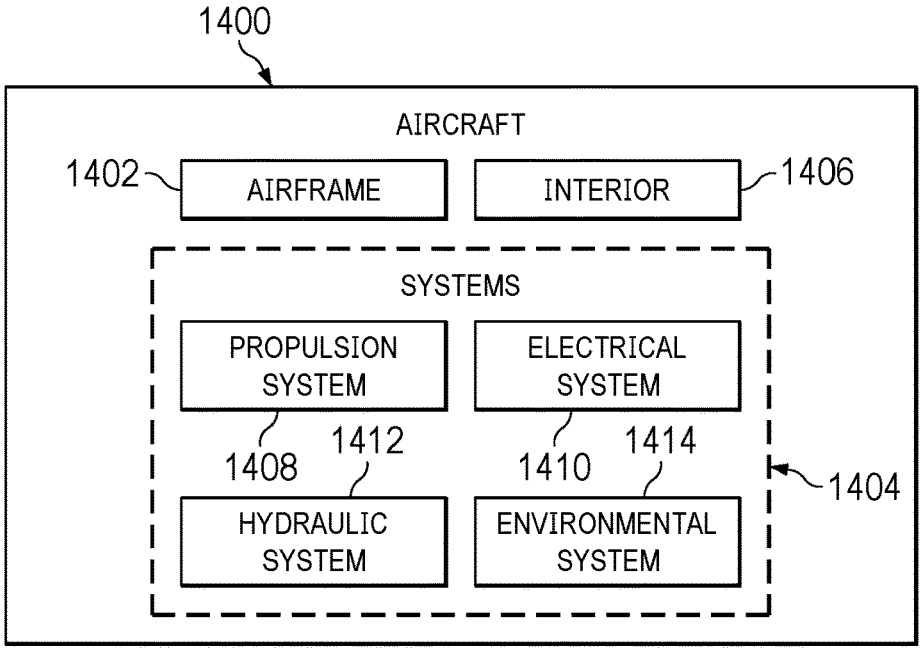

1400
AIRCRAFT
1402
AIRFRAME
INTERIOR
1406
SYSTEMS
PROPULSION SYSTEM
ELECTRICAL SYSTEM
1408
1412
1410
1414
1404
HYDRAULIC SYSTEM
ENVIRONMENTAL SYSTEM

FIG. 14

SEALANT APPLICATION ASSEMBLY AND METHODS OF USE

BACKGROUND INFORMATION

1. Field

The present disclosure relates generally to manufacturing and more specifically to applying sealant to fasteners during manufacturing.

2. Background

During manufacturing, applying sealant to fasteners is performed to improve manufacturing or product performance. Sealants can provide at least one of improvement in adhesion, reducing corrosion or other undesirable effects, and providing sealing against moisture. It can be desirable to provide an automated system and method to apply sealant to fasteners to reduce manufacturing time or improve quality.

Therefore, it would be desirable to have a method and apparatus that takes into account at least some of the issues discussed above, as well as other possible issues.

SUMMARY

An embodiment of the present disclosure provides a sealant application nozzle. The sealant application nozzle comprises a manifold with a incurvate face; manifold bristles extending outward from the incurvate face; and channels within the manifold culminating in outlets exiting through the incurvate face to dispose sealant onto the incurvate face and base of the bristles.

Another embodiment of the present disclosure provides a sealant application assembly. The sealant application assembly comprises a sealant source; a motor configured to apply pressure to the sealant source to extrude sealant from the sealant source; and a sealant application nozzle connected to the sealant source, the sealant application nozzle comprising a incurvate face with outlets configured to dispense sealant and bristles extending outward from the incurvate face.

Yet another embodiment of the present disclosure provides a method of applying sealant to a fastener. The fastener is positioned in contact with a number of bristles of a sealant application nozzle. The fastener is rotated while maintaining contact with the number of bristles to apply sealant to the fastener. The fastener is moved in a vertical direction while rotating the fastener and maintaining contact with the number of bristles.

A yet further embodiment of the present disclosure provides a method of applying sealant to a fastener. Pressure is applied to a sealant source to send sealant from the sealant source into a port of a sealant application nozzle, through channels of the sealant application nozzle, through outlets of the channels, and onto an incurvate face of the sealant application nozzle and base of bristles extending outward from the incurvate face. The fastener is positioned in contact with a number of bristles of a sealant application nozzle. The fastener is rotated while maintaining contact with the number of bristles to apply sealant to the fastener.

The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is an illustration of an aircraft in accordance with an illustrative embodiment;

FIG. **2** is an illustration of a block diagram of a manufacturing environment in accordance with an illustrative embodiment;

FIG. **3** is an illustration of a perspective view of a sealant application assembly in accordance with an illustrative embodiment;

FIG. **4** is an illustration of a perspective view of a sealant application assembly in accordance with an illustrative embodiment;

FIG. **5** is an illustration of a phantom perspective view of a sealant application nozzle in accordance with an illustrative embodiment;

FIG. **6** is an illustration of a front perspective view of a sealant application nozzle in accordance with an illustrative embodiment;

FIG. **7** is an illustration of a top view of a sealant application nozzle in accordance with an illustrative embodiment;

FIG. **8** is an illustration of a top view of a sealant application nozzle with a fastener in accordance with an illustrative embodiment;

FIG. **9** is an illustration of a top view of a sealant application nozzle with a fastener in accordance with an illustrative embodiment;

FIG. **10** is an illustration of a back perspective view of a sealant application assembly with portions in phantom in accordance with an illustrative embodiment;

FIG. **11** is a flowchart of a method of applying sealant to a fastener in accordance with an illustrative embodiment;

FIG. **12** is a flowchart of a method of applying sealant to a fastener in accordance with an illustrative embodiment;

FIG. **13** is an illustration of an aircraft manufacturing and service method in a form of a block diagram in accordance with an illustrative embodiment; and

FIG. **14** is an illustration of an aircraft in a form of a block diagram in which an illustrative embodiment may be implemented.

DETAILED DESCRIPTION

The illustrative examples recognize and take into account one or more different considerations. For example, the illustrative examples recognize and take into account that in current assembly of aircraft structures using robotics, the drilling and fastening is accomplished using dual sided clamp-up with robots. Clamp-up is maintained by the two robots during drilling and fastening processes. The illustrative examples recognize and take into account that in the current assembly of aircraft, a multi-function end effector on the outside robot performs drilling and fastener insertion functions. The illustrative examples recognize and take into account that currently a fastener is fed using tubes from the fastener storage mechanism, and sealant is applied to this fastener once it reaches the end effector. The illustrative examples recognize and take into account that the sealant application mechanism is usually internal to the end effector. The illustrative examples recognize and take into account that internal sealant application adds complexity to the end effector design and operations.

The illustrative examples recognize and take into account that the various movements for providing adequate sealant application to the fastener add to the complexity and weight of the end effector. The illustrative examples recognize and take into account that replenishment of sealant supply requires the end effector operations to be stopped. The illustrative examples recognize and take into account that the cleaning/replacement of sealant applicator tips/brushes also requires the end effector operations be stopped. The illustrative examples recognize and take into account that inspection of the quality of the sealant application to the fastener is also difficult as it is not visible prior to the insertion into the drilled hole.

Current solutions of sealant application systems are internal to the end effector. These systems complicate the design of the end effector and do not provide visible inspection of the quality of applied sealant.

The illustrative examples provide a sealant application assembly that can apply sealant to fasteners outside of end effectors. The sealant application assembly is configured to apply sealant to fasteners having a plurality of different fastener diameters.

Turning now to FIG. **1**, an illustration of an aircraft is depicted in accordance with an illustrative embodiment. Aircraft **100** has wing **102** and wing **104** attached to body **106**. Aircraft **100** includes engine **108** attached to wing **102** and engine **110** attached to wing **104**.

Body **106** has tail section **112**. Horizontal stabilizer **114**, horizontal stabilizer **116**, and vertical stabilizer **118** are attached to tail section **112** of body **106**.

Aircraft **100** is an example of an aircraft with fasteners joining components. The fasteners in aircraft **100** can have sealant applied by sealant application assembly **200** of FIG. **2** during manufacturing.

Turning now to FIG. **2**, an illustration of a block diagram of a manufacturing environment is depicted in accordance with an illustrative embodiment. Sealant application assembly **200** in manufacturing environment **202** can apply sealant to fasteners to be used in aircraft **100** of FIG. **1**. Fasteners with sealant applied by sealant application assembly **200** can be present in at least one of body **106**, wing **102**, or wing **104** of FIG. **1**.

Sealant application assembly **200** comprises sealant source **204**, motor **206** configured to apply pressure **207** to sealant source **204** to extrude sealant **208** from sealant source **204**, and sealant application nozzle **210** connected to sealant source **204**. Sealant application nozzle **210** comprises incurvate face **212** with outlets **214** configured to dispense sealant **208** and bristles **216** extending outward from incurvate face **212**.

Motor **206** can take any desirable form to apply pressure **207** to sealant source **204**. In some illustrative examples, motor **206** is screw motor **220**. Screw pitch **222** can be adjusted based on a desired amount of pressure **207** to be applied to sealant source **204**. In some illustrative examples, a pneumatic valve is present to apply pressure to sealant source **204**.

Sealant source **204** takes any desirable form. In some illustrative examples, sealant source **204** takes the form of cartridge **224**. In some illustrative examples, sealant source **204** takes the form of syringe **226**.

Outlet **228** of sealant source **204** is connected to sealant application nozzle **210** by tubing **230**. In this illustrative example, sealant **208** from sealant source **204** enters sealant application nozzle **210** at port **232**. From port **232**, sealant **208** travels through channels **234** within sealant application nozzle **210**. Channels **234** have any desirable shape, position, and quantity based on viscosity **235** of sealant **208** and locations of outlets **214**. Channels **234** deliver sealant **208** to outlets **214**.

Sealant application nozzle **210** comprises manifold **237** with incurvate face **212**, channels **234** extending through manifold **237** and culminating in outlets **214** exiting through incurvate face **212**, bristles **216** extending outward from incurvate face **212**, and channels **234** within manifold **237** culminating in outlets **214** exiting through incurvate face **212** to dispose sealant **208** onto the incurvate face **212** and base **239** of bristles **216**. Base **239** of bristles **216** connect bristles **216** to incurvate face **212**.

In some illustrative examples, sealant application nozzle **210** is referred to as application brush **276**. In some illustrative examples, manifold **237** and bristles **216** are formed of polymeric material **274**.

Outlets **214** dispense sealant **208** to within incurvate face **212**. Sealant **208** is dispersed within and onto incurvate face **212**. Sealant **208** travels between bristles **216** of sealant application nozzle **210**. As sealant **208** is supplied to incurvate face **212**, some excess can fall from sealant application nozzle **210**.

In some illustrative examples, sealant application assembly **200** further comprises drip tray **236** positioned below sealant application nozzle **210** and configured to collect excess sealant falling from sealant application nozzle **210**. Drip tray **236** can prevent excess sealant from falling onto a manufacturing floor.

Sealant application assembly **200** is configured to apply sealant **208** to fasteners **238** of plurality of different diameters **240**. More specifically, bristles **216** are configured to apply sealant **208** to fasteners **238** of plurality of different diameters **240**.

For example, sealant application assembly **200** can apply sealant **208** to fastener **242** with diameter **244** and second fastener **246** with second diameter **248** different from diameter **244**. Sealant application nozzle **210** can apply sealant **208** to fastener **242** with diameter **244** and second fastener **246** with second diameter **248**.

To apply sealant **208** to fasteners **238** of plurality of different diameters **240**, tips **250** of bristles **216** form variable curvature **252** configured to contact a fastener, such as fastener **242** or second fastener **246**. Variable curvature **252** accommodates fasteners **238** of plurality of different diameters **240**.

Tips **250** of bristles **216** form opening **280** for accepting fasteners **238**. Opening **280** has variable curvature **252** and is configured to apply sealant to fasteners **238** having plurality of different diameters **240**.

Fasteners **238** having greater diameters will contact a larger quantity of bristles **216** than fasteners **238** having smaller diameters. For example, fastener **242** having diameter **244** contacts number of bristles **254** of sealant application nozzle **210** during application of sealant **208** to fastener **242**. Second fastener **246** having second diameter **248** contacts second number of bristles **256** of sealant application nozzle **210** during application of sealant **208** to second fastener **246**. When second diameter **248** is greater than diameter **244**, second number of bristles **256** has a greater quantity of bristles. In some illustrative examples, second number of bristles **256** includes number of bristles **254**.

Bristles **216** are positioned in any desirable arrangement. In some illustrative examples, bristles **216** are randomly arranged. In some illustrative examples, bristles **216** are equally spaced. In some illustrative examples, bristles **216** have more than one arrangement. In some illustrative examples, bristles **216** are arranged in columns.

In some illustrative examples, bristles **216** are arranged in rows **258**, and each row comprises a variable curvature formed by tips of bristles in the row. For example, rows **258** includes first row **260** and second row **262**. First row **260** comprises first set of bristles **264** of bristles **216**. First set of bristles **264** has tips **266** of tips **250**. Tips **266** form variable curvature **252** in first row **260**.

Second row **262** comprises second set of bristles **268** of bristles **216**. Second set of bristles **268** has tips **270** of tips **250**. Tips **270** form variable curvature **252** in second row **262**.

Outlets **214** are configured to distribute sealant **208** to bristles **216**. Outlets **214** have any desirable quantity, spacing, and layout. In some illustrative examples, outlets **214** are symmetrical along a centerplane **267** extending through rows **258**. In other illustrative examples, outlets **214** are not symmetrical. In some illustrative examples, outlets **214** are positioned where bristles would otherwise be positioned. In some illustrative examples, outlets **214** are positioned in a top half of manifold **237**. In other illustrative examples, outlets **214** are positioned evenly across manifold **237**. In some illustrative examples, outlets **214** are positioned in a bottom half of manifold **237**.

In some illustrative examples, each bristle of a respective row comprises a tip with a different angle than every other bristle of the respective row. For example, each bristle of first set of bristles **264** in first row **260** has a tip with a different angle than every other bristle of first set of bristles **264**. As another example, each bristle of second set of bristles **268** in second row **262** has a tip with a different angle than every other bristle of second set of bristles **268**.

Although tips **250** form variable curvature **252** to accommodate plurality of different diameters **240**, in some illustrative examples, diameter **272** of incurvate face **212** is constant.

In some illustrative examples, camera **278** is positioned to image a fastener within incurvate face **212** as the fastener moves relative to sealant application nozzle **210**. In some illustrative examples, camera **278** is positioned to image a fastener, such as fastener **242**, as sealant **208** is applied to fastener **242**. In some illustrative examples, camera **278** is positioned to image a fastener, such as fastener **242**, after sealant **208** is applied to fastener **242**.

Imaging from camera **278** is used to determine if a desired surface is covered in sealant **208**. In some illustrative examples, sealant **208** is applied to shank **284** of fastener **242**. In some illustrative examples, sealant **208** is applied to bottom of head **282** of fastener **242**. In some illustrative examples, sealant **208** is applied to threads **286** of fastener **242**. The portion of fastener **242** can be referred to as a desired surface.

In some illustrative examples, channels **234** are symmetrical along a centerplane **267** extending through midpoint **269** of the incurvate face **212**. In some illustrative examples, channels **234** are positioned in a top half of manifold **237**.

In some illustrative examples, sealant application nozzle **210** is disposable. When sealant application nozzle **210** is disposable, maintenance and cleaning efforts can be reduced. In some illustrative examples, sealant application nozzle **210** can be attached to the remainder of sealant application assembly **200** using a quick-release approach. When a quick release connector is utilized, sealant application nozzle **210** can be quickly and easily replaced during production. Sealant application nozzle **210** can be removed and replaced either for cleaning or for disposal. In some illustrative examples, sealant application nozzle **210** is removed and replaced with a nozzle configured to apply sealant to fasteners having different diameters.

The illustration of manufacturing environment **202** in FIG. **2** is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

In some illustrative examples, sealant source **204** is connected to tubing **230** by a luer connector. In some illustrative examples, tubing **230** may also be referred to as a needle.

Although not depicted, a heater can be associated with sealant source. In some illustrative examples, sealant source **204** can be maintained at a desired temperature to control viscosity **235** and flow of sealant **208**.

Turning now to FIG. **3**, an illustration of a perspective view of a sealant application assembly is depicted in accordance with an illustrative embodiment. Sealant application assembly **300** is a physical implementation of sealant application assembly **200** of FIG. **2**.

Sealant application assembly **300** comprises sealant source **302**, motor **304** configured to apply pressure to sealant source **302** to extrude sealant from sealant source **302**, and sealant application nozzle **306** connected to sealant source **302**. In this illustrative example, tubing **308** connects sealant source **302** to sealant application nozzle **306**.

In this illustrative example, camera **310** is present in sealant application assembly **300** to inspect a fastener. Camera **310** is positioned to image a fastener after application of a sealant by sealant application nozzle **306**. Camera **310** is positioned such that the fastener can be inspected at least one of during or just after application of the sealant. If there is an insufficient amount of sealant on the fastener, the fastener can be placed back in contact with sealant application nozzle to apply additional sealant to the fastener. In this illustrative example, the camera is positioned such that a fastener can be inspected as it moves relative to sealant application nozzle **306**.

Sealant application nozzle **306** is positioned above collection tray **312**. Collection tray **312** catches sealant that falls from sealant application nozzle **306**. Sealant application nozzle **306** is connected to mount **314** to elevate sealant application nozzle **306** to sealant source **302**. Mount **314** is configured to allow for a fastener to contact sealant application nozzle **306** without impacting mount **314**.

Turning now to FIG. **4**, an illustration of a perspective view of a sealant application assembly is depicted in accordance with an illustrative embodiment. View **400** is a view within the box labeled as FIG. **4** in FIG. **3**.

Sealant application nozzle **306** comprises incurvate face **402** with outlets **404** configured to dispense sealant **406** and bristles **408** extending outward from incurvate face **402**. To apply sealant to a fastener, the fastener is placed within incurvate face **402** and in contact with bristles **408**.

Turning now to FIG. **5**, an illustration of a phantom perspective view of a sealant application nozzle is depicted in accordance with an illustrative embodiment. Sealant application nozzle **500** is a physical implementation of sealant application nozzle **210** of FIG. **2**. Sealant application nozzle **500** can be the same as sealant application nozzle **306** of FIGS. **3** and **4**.

Sealant application nozzle **500** comprises manifold **502** with incurvate face **504**, channels **506** extending through

manifold **502** and culminating in outlets **508** exiting through incurvate face **504**, and bristles **510** extending outward from incurvate face **504**. To apply sealant to a fastener, sealant is supplied to sealant application nozzle **500** through port **512**. Sealant enters through port **512** and is distributed to channels **506**. Sealant exits channels **506** at outlets **508** in incurvate face **504**. The sealant spreads across incurvate face **504** and between bristles **510**. By placing a fastener in contact with a number of bristles of bristles **510** and rotating the fastener, sealant is applied to the fastener.

Sealant application nozzle **500** is formed of a material configured to contact a fastener without undesirably affecting the fastener. In some illustrative examples, manifold **502** and bristles **510** are formed of a polymeric material. Manifold **502** has centerplane **514**. In some illustrative examples, at least one of bristles **510** or outlets **508** are symmetrical about centerplane **514**.

Turning now to FIG. **6**, an illustration of a front perspective view of a sealant application nozzle is depicted in accordance with an illustrative embodiment. View **600** is a front perspective view of sealant application nozzle **500** of FIG. **5**.

As can be seen in view **600**, bristles **510** are arranged in rows **602**. Rows **602** include row **604**, row **606**, row **608**, row **610**, row **612**, and row **614**. As depicted, row **608**, row **610**, row **612**, and row **614** each have the same quantity of bristles. In this illustrative example, row **604** and row **606** have fewer bristles than the remaining rows.

Outlets **508** extend through incurvate face **504** in row **604** and row **606**. In this illustrative example, row **604** and row **606** have fewer bristles than row **608** due to outlets **508**. In this illustrative example, outlets **508** are symmetrical along centerplane **514** extending through rows **602**. In this illustrative example, outlets **508** are positioned in a top half of manifold **502**.

In this illustrative example, each bristle of a respective row comprises a tip with a different angle than every other bristle of the respective row. For example, each bristle of row **604** comprises a tip with a different angle than every other bristle of row **604**. Likewise, each bristle of row **608** comprises a tip with different angle than every other bristle of row **608**.

Due to the concavity of incurvate face **504**, bristles in a respective row can have different lengths. The length of each respective bristle in a row is configured to form variable curvature **618**.

To apply sealant to fasteners of a plurality of different diameters, tips **616** of bristles **510** form variable curvature **618** configured to contact a fastener. Variable curvature **618** accommodates fasteners of a plurality of different diameters. Each row of rows **602** forms variable curvature **618**.

Turning now to FIG. **7**, an illustration of a top view of a sealant application nozzle is depicted in accordance with an illustrative embodiment. View **700** is a top-down view of sealant application nozzle **500** of FIGS. **5-6**. View **700** is a view of sealant application nozzle **500** with a series of circles representing various diameters of fasteners.

Bristles **510** are configured to apply sealant to fasteners of a plurality of different diameters. To apply sealant to fasteners of a plurality of different diameters, tips **616** of bristles **510** form variable curvature **618** are configured to contact a fastener. Variable curvature **618** accommodates fasteners of a plurality of different diameters.

Fasteners having greater diameters will contact a larger quantity of bristles than fasteners having smaller diameters. Circle **702**, circle **704**, and circle **706** depict diameters of fasteners that would desirably have sealant applied by sealant application nozzle **500**. Sealant application nozzle **500** is designed to apply sealant to fasteners that have diameters between the diameter of circle **706** and circle **702**. Variable curvature **618** has been designed to apply sealant to each of circle **702**, circle **704**, and circle **706**.

Circle **702** represents the diameter of a small fastener that contacts three bristles of bristles **510** during application of sealant to the fastener. Circle **704** represents the diameter of a fastener that contacts between three and five bristles of bristles **510** during application of sealant to the fastener. Circle **704** is larger than circle **702**, thus circle **704** contacts more bristles of bristles **510**. Circle **706** is larger than circle **704** and contacts more bristles of bristles **510**.

Circle **708** represents a diameter of a fastener that will not have sealant applied by sealant application nozzle **500**. Circle **708** is too large to contact variable curvature **618**.

As can be seen in view **700**, diameter **710** of incurvate face **504** is constant. As can be seen in view **700**, tips **616** of bristles **510** form variable curvature **618**. As can be seen in view **700**, each row comprises variable curvature **618** formed by tips of bristles in the row.

Turning now to FIG. **8**, an illustration of a top view of a sealant application nozzle with a fastener is depicted in accordance with an illustrative embodiment. View **800** is a top view of sealant application nozzle **500** of FIGS. **5-7** with a small fastener.

In view **800**, fastener **802** is in contact with some of bristles **510**. Fastener **802** has diameter **804**. Fastener **802** with diameter **804** contacts number of bristles **806** of sealant application nozzle **500** during application of sealant to fastener **802**.

Turning now to FIG. **9**, an illustration of a top view of a sealant application nozzle with a fastener is depicted in accordance with an illustrative embodiment. View **900** is a top view of sealant application nozzle **500** of FIGS. **5-8** with a large fastener.

In view **900**, second fastener **902** having second diameter **904** contacts second number of bristles **906** of sealant application nozzle **500** during application of sealant to second fastener **902**. When second diameter **904** is greater than diameter **804**, second number of bristles **906** has a greater quantity of bristles. As depicted, second number of bristles **906** includes number of bristles **806**. In view **900**, second fastener **902** contacts all of bristles **510**.

As depicted in view **900**, channels **506** are symmetrical along centerplane **514** extending through a midpoint of incurvate face **504**. Channels **506** distribute sealant to bristles **510** to apply sealant to second fastener **902**.

The illustration of sealant application nozzle **500** in FIGS. **5-9** is not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary.

For example, the size, shape, position, and quantity of outlets **508** is set based on a type and viscosity of sealant to be applied. As another example, the size, shape, position, and quantity of channels **506** is set based on a type and viscosity of sealant to be applied. As yet another example, variable curvature **618** and angles of tips **616** of bristles **510** are set based on diameters of fasteners to have sealant applied. As yet a further example, the size, shape, position, and quantity of bristles **510** is set based on a size of fasteners to be sealed and the sealant to be used.

Turning now to FIG. **10**, an illustration of a back perspective view of a sealant application assembly with portions in phantom is depicted in accordance with an illustra-

tive embodiment. View **1000** is a view of a back perspective view of sealant application assembly **1006**. In view **1000**, fastening end effector **1002** holds fastener **1004** to apply sealant to fastener **1004** using sealant application assembly **1006**. In view **1000**, fastener **1004** is placed into contact with bristles **1008** of sealant application nozzle **1010**. Sealant source **1012** provides sealant to tubing **1014** that connects sealant source **1012** to channels **1016** in sealant application nozzle **1010**.

Camera **1018** is positioned to image fastener **1004**. In some illustrative examples, camera **1018** is positioned to image fastener **1004** during application of sealant to fastener **1004** by sealant application nozzle **1010**. In some illustrative examples, camera **1018** is positioned to image fastener **1004** following application of sealant to fastener **1004** by sealant application nozzle **1010**.

A desired application is 100% coverage of a designated surface of fastener **1004**. In some illustrative examples, the designated surface of fastener **1004** is the shank of fastener **1004**. In some illustrative examples, the designated surface of fastener **1004** is a bottom of the head of fastener **1004**. If a portion of the designated surface of fastener **1004** is not covered by sealant, additional sealant will be applied to fastener **1004**.

Sealant is applied to fastener **1004** as fastening end effector **1002** moves fastener **1004** in at least one of direction **1020** or direction **1022**. By moving fastener **1004** in direction **1022**, the length of fastener **1004** is coated by the sealant. By moving fastener **1004** in direction **1020**, the circumference of fastener **1004** is coated by the sealant.

Turning now to FIG. **11**, a flowchart of a method of applying sealant to a fastener is depicted in accordance with an illustrative embodiment. Method **1100** can be performed in manufacturing aircraft **100** of FIG. **1**. Method **1100** can be performed by sealant application assembly **200** of FIG. **2**. Method **1100** can be performed by sealant application assembly **300** of FIGS. **3-4**. Method **1100** can be performed using sealant application nozzle **500** of FIGS. **5-9**. Method **1100** can be performed by sealant application assembly **1006** of FIG. **10**.

Method **1100** positions the fastener in contact with a number of bristles of a sealant application nozzle (operation **1102**). Method **1100** rotates the fastener while maintaining contact with the number of bristles to apply sealant to the fastener (operation **1104**). Method **1100** moves the fastener in a vertical direction while rotating the fastener and maintaining contact with the number of bristles (operation **1106**). Afterwards, method **1100** terminates.

In some illustrative examples, method **1100** applies pressure to a sealant source to send sealant into the sealant application nozzle (operation **1108**). In some illustrative examples, the pressure is applied by a motor. In some illustrative examples, the pressure is applied by a plunger.

In some illustrative examples, method **1100** images the fastener as the fastener moves relative to the sealant application nozzle (operation **1110**). In some illustrative examples, method **1100** images the fastener while the fastener is in contact with the sealant application nozzle. In some illustrative examples, method **1100** images the fastener while the fastener is held above the sealant application nozzle.

In some illustrative examples, method **1100** determines if an entire designated surface of the fastener is covered by sealant based on imaging the fastener (operation **1112**). In some illustrative examples, applying sealant to the fastener comprises applying sealant to a shank of the fastener (operation **1114**). In some illustrative examples, applying sealant to the fastener comprises applying sealant to a bottom of a head of the fastener (operation **1116**).

In some illustrative examples, method **1100** positions a second fastener in contact with a second number of bristles of the sealant application nozzle, wherein the second number of bristles has a greater quantity of bristles, and wherein the second number of bristles includes the number of bristles (operation **1118**). In some illustrative examples, method **1100** rotates the second fastener while maintaining contact with the second number of bristles to apply sealant to the second fastener (operation **1120**). In some illustrative examples, method **1100** moves the second fastener in a vertical direction while rotating the second fastener and maintaining contact with the second number of bristles (operation **1122**).

Turning now to FIG. **12**, a flowchart of a method of applying sealant to a fastener is depicted in accordance with an illustrative embodiment. Method **1200** can be performed in manufacturing aircraft **100** of FIG. **1**. Method **1200** can be performed by sealant application assembly **200** of FIG. **2**. Method **1200** can be performed by sealant application assembly **300** of FIGS. **3-4**. Method **1200** can be performed using sealant application nozzle **500** of FIGS. **5-9**. Method **1200** can be performed by sealant application assembly **1006** of FIG. **10**.

Method **1200** sends sealant from A sealant source into a port of a sealant application nozzle, through channels of the sealant application nozzle, through outlets of the channels, and onto an incurvate face of the sealant application nozzle and base of bristles extending outward from the incurvate face (operation **1202**). Method **1200** positions the fastener in contact with a number of bristles of a sealant application nozzle (operation **1204**). Method **1200** rotates the fastener while maintaining contact with the number of bristles to apply sealant to the fastener (operation **1206**). Afterwards, method **1200** terminates.

In some illustrative examples, method **1200** applies pressure to the sealant source to send the sealant from the sealant source into the port of the sealant application nozzle (operation **1207**). In some illustrative examples, method **1200** images the fastener as the fastener moves relative to the sealant application nozzle (operation **1208**). In some illustrative examples, method **1200** determines if an entire designated surface of the fastener is covered by sealant based on imaging the fastener (operation **1210**). In some illustrative examples, method **1200** applies additional sealant to the fastener using the number of bristles in response to a determination that the entire designated surface of the fastener is not covered by sealant (operation **1212**).

In some illustrative examples, applying sealant to the fastener comprises applying sealant to a shank of the fastener (operation **1214**). In some illustrative examples, applying sealant to the fastener comprises applying sealant to a bottom of a head of the fastener (operation **1216**).

As used herein, the phrase "at least one of," when used with a list of items, means different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, "at least one of item A, item B, or item C" may include, without limitation, item A, item A and item B, or item B. This example also may include item A, item B, and item C or item B and item C. Of course, any combinations of these items may be present. In other examples, "at least one of" may be, for example, without limitation, two of item A; one of item B; and ten of item C; four of item B and seven of item C; or other suitable combinations. The item may be a particular object, thing, or a category. In other words, at least one of means any

combination items and number of items may be used from the list but not all of the items in the list are required.

As used herein, "a number of," when used with reference to items means one or more items.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent at least one of a module, a segment, a function, or a portion of an operation or step.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram. Some blocks may be optional. For example, operation **1108** through operation **1122** maybe optional. As another example, operation **1208** through operation **1216** maybe optional.

Illustrative embodiments of the present disclosure may be described in the context of aircraft manufacturing and service method **1300** as shown in FIG. **13** and aircraft **1400** as shown in FIG. **14**. Turning first to FIG. **13**, an illustration of an aircraft manufacturing and service method in a form of a block diagram is depicted in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **1300** may include specification and design **1302** of aircraft **1400** in FIG. **14** and material procurement **1304**.

During production, component and subassembly manufacturing **1306** and system integration **1308** of aircraft **1400** takes place. Thereafter, aircraft **1400** may **1400** may go through certification and delivery **1310** in order to be placed in service **1312**. While in service **1312** by a customer, aircraft **1400** is scheduled for routine maintenance and service **1314**, which may include modification, reconfiguration, refurbishment, or other maintenance and service.

Each of the processes of aircraft manufacturing and service method **1300** maybe performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

With reference now to FIG. **14**, an illustration of an aircraft in a form of a block diagram is depicted in which an illustrative embodiment may be implemented. In this example, aircraft **1400** is produced by aircraft manufacturing and service method **1300** of FIG. **13** and may include airframe **1402** with plurality of systems **1404** and interior **1406**. Examples of systems **1404** include one or more of propulsion system **1408**, electrical system **1410**, hydraulic system **1412**, and environmental system **1414**. Any number of other systems may be included.

Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **1300**. One or more illustrative embodiments may be manufactured or used during at least one of component and subassembly manufacturing **1306**, system integration **1308**, in service **1312**, or maintenance and service **1314** of FIG. **13**.

The illustrative examples provide methods and a sealant application assembly. A fastener is moved to a home sealant applicator position. The fastener detail information is accessed. The fastener detail information can include at least one of type, diameter, and length.

The fastener is lowered into the incurvate face of a sealant brush via a path determined by the fastener diameter. A sealant source will begin to extrude sealant into the bristles of the brush assembly.

Custom sealant passages will promote even distribution throughout the application brush. The end effector will slowly retract and rotate the fastener to distribute sealant along the outer surface of the fastener.

In some illustrative examples, as the end effector clears the sealant brush applicator, a camera can be used to verify appropriate sealant application. If desired sealant coverage is achieved, sealant application is complete, and the fastener can then be used in further manufacturing. If desired sealant coverage is not achieved, the fastener is moved to a home position and proceeds through sealant application again so that sealant application can be repeated.

The illustrative examples present a sealant application module for applying sealant to fasteners for use in outside mould line (OML) fastening end effectors. A fastener is selected and picked up by the gripper of the end effector, then transferred to the sealant application module where sealant is applied. For sealant application, a brush with flexible applicator tips is used. This brush has multiple inlet ports which are fed a consistent flow of sealant through a sealant syringe. A fastener rotation and translation motion using the end effector is used to apply the sealant. The sealant application is verified with the help of a camera.

The use of the sealant application assembly with single function fastening end effectors reduces complexity of the fastening end effector. The fastener is picked by the fastening end effector and taken to the sealant applicator mechanism which is external to the end effector. Separating the sealant application assembly from the end effector simplifies the design and operations of the fastening end effector. The sealant applicator mechanism applies the sealant to the fastener and then the fastener is taken by the end effector to insert the fastener into a drilled hole.

The novel features of these illustrative examples include a syringe needle attached to a motor-driven sealant plunger which extrudes sealant onto the brush assembly. The syringe is connected with a luer to an application brush that will provide ample sealant within the flexible bristle to facilitate coverage on the fastener. In some illustrative examples, the OML end effector provides the rotation necessary to apply sealant to the full fastener diameter. In some illustrative examples, during retraction of the fastener from the brush assembly, a camera will verify appropriate and complete sealant application.

The sealant application nozzle of the illustrative examples includes multiple sealant passages leading to outlets strategically positioned within the bristles for optimal sealant distribution and minimum waste. The syringe comes with a luer lock to ensure a good connection, minimize leakage, and add inherent stiffness to the joint.

The illustrative examples use an external simplified sealant applicator system with the ability to check on the quality of applied sealant using an in-process camera.

In the illustrative examples, sealant application to the fastener is conducted external of a fastening end effector. Applying the sealant to the fastener outside of a fastening

end effector provides visibility of the sealant application process. Visibility of the sealant application process allows for quality inspection of the applied sealant. Conducting sealant application to the fastener external of the fastening end effector simplifies the fastening end effector. By the fastening end effector not including internal sealant application, the end effector operations do not have to be stopped for sealant replenishment as well cleaning/replacement of brushes.

The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other illustrative embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. A sealant application nozzle that comprises:
a manifold that comprises an incurvate face;
bristles that comprise a base set within and that extend outward from the incurvate face, wherein the bristles are arranged in rows, and wherein each row comprises a variable curvature formed by tips of bristles in the row; and
channels within the manifold that culminate in outlets that exit through the incurvate face configured to dispose sealant onto the incurvate face and the base of the bristles.

2. The sealant application nozzle of claim **1**, wherein the manifold and the bristles are formed of a polymeric material.

3. The sealant application nozzle of claim **1**, wherein the outlets are symmetrical along a centerplane extending through the rows.

4. The sealant application nozzle of claim **1**, wherein the outlets are positioned in a top half of the manifold.

5. The sealant application nozzle of claim **1**, wherein the channels are symmetrical along a centerplane extending through a midpoint of the incurvate face.

6. The sealant application nozzle of claim **1**, wherein each bristle in a respective row comprises a tip with a different angle than every other bristle of the respective row.

7. The sealant application nozzle of claim **1**, wherein the bristles are formed from a same material as the manifold.

8. A sealant application assembly that comprises:
a sealant source;
a motor configured to apply pressure to the sealant source and extrude sealant from the sealant source; and
a sealant application nozzle connected to the sealant source, wherein the sealant application nozzle comprises an incurvate face that comprises:
outlets configured to dispense sealant; and
bristles that extend outward from the incurvate face.

9. The sealant application assembly of claim **8** further comprising:
a camera positioned to image a fastener within the incurvate face as it moves relative to the sealant application nozzle.

10. The sealant application assembly of claim **8** further comprising:
a drip tray positioned below the sealant application nozzle and configured to collect excess sealant falling from the sealant application nozzle.

11. The sealant application assembly of claim **8**, wherein the motor is a screw motor.

12. The sealant application assembly of claim **8**, wherein the bristles are configured from a same material as the incurvate face.

13. The sealant application assembly of claim **8**, wherein tips of the bristles form a variable curvature configured to contact a fastener.

14. The sealant application assembly of claim **8**, wherein the bristles are formed of a polymeric material.

15. A method of applying a sealant to a fastener, the method comprising:
positioning the fastener in contact with bristles of a sealant application nozzle comprising:
a manifold comprising an incurvate face;
the bristles comprising a base set within and extending outward from the incurvate face, wherein the bristles are arranged in rows, and wherein each row comprises a variable curvature formed by tips of bristles in the row; and
channels within the manifold culminating in outlets exiting through the incurvate face disposing sealant onto the incurvate face and the base of the bristles;
rotating the fastener while maintaining contact with the bristles to apply the sealant to the fastener; and
moving the fastener in a vertical direction while rotating the fastener and maintaining contact with the bristles.

16. The method of claim **15** further comprising:
applying pressure to a sealant source to send sealant into the sealant application nozzle.

17. The method of claim **15** further comprising:
imaging the fastener as the fastener moves relative to the sealant application nozzle.

18. The method of claim **17** further comprising:
determining if an entire designated surface of the fastener is covered by sealant based on imaging the fastener.

19. The method of claim **15**, wherein applying sealant to the fastener comprises applying sealant to a shank of the fastener.

20. The method of claim **15**, wherein applying sealant to the fastener comprises applying sealant to a bottom of a head of the fastener.

21. The method of claim **15** further comprising:
positioning a second fastener in contact with second bristles extending outward from the incurvate face of the sealant application nozzle, wherein the second bristles are additional to the bristles;
rotating the second fastener while maintaining contact with the second bristles to apply sealant to the second fastener; and
moving the second fastener in a vertical direction while rotating the second fastener and maintaining contact with the second bristles.

22. A method of applying sealant to a fastener, the method comprising:
sending sealant from a sealant source into a port of a sealant application nozzle, through channels of the sealant application nozzle, through outlets of the channels, and onto an incurvate face of the sealant application nozzle and base of bristles extending outward from the incurvate face;
positioning the fastener in contact with bristles of a sealant application nozzle comprising:
a manifold comprising the incurvate face;

the bristles comprising a base set within and extending outward from the incurvate face, wherein the bristles are arranged in rows, and wherein each row comprises a variable curvature formed by tips of bristles in the row; and

channels within the manifold culminating in outlets exiting through the incurvate face disposing sealant onto the incurvate face and the base of the bristles; and

rotating the fastener while maintaining contact with the bristles to apply sealant to the fastener.

23. The method of claim **22** further comprising:

applying pressure to the sealant source to send the sealant from the sealant source into the port of the sealant application nozzle.

24. The method of claim **22** further comprising:

imaging the fastener as the fastener moves relative to the sealant application nozzle.

25. The method of claim **24** further comprising:

determining if an entire designated surface of the fastener is covered by sealant based on imaging the fastener.

26. The method of claim **25** further comprising:

applying additional sealant to the fastener using the bristles in response to a determination that the entire designated surface of the fastener is not covered by sealant.

27. The method of claim **22**, wherein applying sealant to the fastener comprises applying sealant to a shank of the fastener.

28. The method of claim **22**, wherein applying sealant to the fastener comprises applying sealant to a bottom of a head of the fastener.

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